COMPUTERIZED SYSTEM AND METHOD FOR CORRECTING TOOTH-SIZE
DISCREPANCIES

FIELD OF THE INVENTION

The present invention relates to the field of orthodontics, in

particular a computerized system and method for identifying

and correcting tooth-size discrepancies, and determining a

5   recommended arch size predicated on a patient's cranial-facial

morphology and tooth size.

BACKGROUND INFORMATION

In the field of orthodontics, a mathematical ratio exists

10   between the size (mesiodistal width) of the upper (maxillary)

and lower (mandibular) teeth. This mathematical ratio should

exist in an ideal dental occlusion. More often than not, and

particularly in patients with orthodontic problems, a tooth-

size discrepancy exists. Although there are no reliable

15   epidemiological studies confirming these statistics, it is

estimated that approximately one-third of the American public

have tooth sizes that are proportional and within a reasonable

range of an ideal occlusion. The remaining two-thirds of the

American public, however, have teeth where the mathematical

20   ratio is not ideal and there exists a modest to severe tooth-

size discrepancy or incompatibility.

In a scientific research paper entitled "Disharmony in Tooth

Size and Its Relation to the Analysis and Treatment of

1

Malocclusion" by Dr. Wayne A. Bolton, a method is described for identifying the presence and magnitude of a tooth-size discrepancy (the "Bolton Analysis"). This method may be performed on the six anterior teeth (two canines, two laterals, and two central incisors) or on twelve teeth (the six anterior teeth, the four premolar teeth, and the two first molar teeth). The mathematical ratio is compared to the ideal mathematical ratio, which is 0.772 for the six anterior teeth, and 0.913 for the twelve teeth analysis. This comparison identifies any existing tooth-size discrepancy and the magnitude of the tooth-size discrepancy, which is the difference between the mathematical ratio and the ideal mathematical ratio.

Typically, the Bolton Analysis is performed using the tables provided in Bolton's paper, a slide rule, which is no longer manufactured, or a calculator. Therefore, determining the existence of a tooth-size discrepancy using the Bolton Analysis can be very tedious and time consuming. While the Bolton Analysis determines the existence and the magnitude of a tooth-size discrepancy, it does not quantify the mathematical correction necessary in the maxillary and/or mandibular teeth to achieve an ideal occlusion. Thus, there exists a need for a computerized system that measures teeth and accurately determines the existence and magnitude of a tooth-size discrepancy in an easy and expeditious manner.

2

The failure of an orthodontist to recognize the existence and amount of the tooth-size discrepancy during diagnosis, and to attain a close to ideal ratio of tooth structure during treatment, may result in treatment problems, such as crowding

5   or spacing of the maxillary and/or mandibular teeth. Deviations from the ideal ratio may also result in a relapse of treatment and/or functional, aesthetic and health problems.

A problem arises, however, when the orthodontist attempts to

10   correct the tooth-size discrepancy determined using the Bolton Analysis. Since the results of the Bolton Analysis are directly related to a ratio, the results do not accurately address the amount of actual anatomical correction necessary in either the maxillary or mandibular arch. As soon as a

15   change is undertaken in any direction, the ratio changes. An orthodontist assuming that a tooth-size discrepancy can be corrected merely by adding to or removing the amount of tooth structure indicated by the results of the Bolton Analysis, in either the maxillary or mandibular arch, will err. Moreover,

20   the results of the Bolton Analysis do not clearly demonstrate to the orthodontist or researcher the actual tooth or teeth prompting the tooth-size discrepancy. Thus, there exists a further need for a computerized system that determines the amount of anatomical correction necessary using the results of

25   the Bolton Analysis. It would be desirable if this system would illustrate, on a monitor and/or in a printer output,

3

the actual and average size of each tooth so that it is immediately apparent to the doctor the tooth or teeth that may be responsible for the tooth-size discrepancy.

5   Preformed arch wires such as super-elastic preformed arch wires are frequently used during the first and second phases of treatment to level, align, torque, and/or shape the teeth and the arches. Current orthodontic use of preformed arch wires (one for the maxillary arch, one for the mandibular

10   arch) means that approximately 17% of patients are treated with an arch wire that is too large and 17% of patients are treated with an arch wire that is too small. Since these preformed arch wires are not adjustable to the patient's facial size, they may create problems by over expansion or

15   constriction of the maxillary and/or mandibular arch. These problems might be corrected later in treatment, when it is least desired, and would extend the treatment time. In addition, the use of these preformed wires may also result in "round tripping," i.e., moving the teeth in the wrong

20   direction and then having to recorrect the teeth. Thus, there exists a further need for a computerized system that determines the ideal arch wire size to effectuate a more precise and stable treatment.

25   **SUMMARY OF THE INVENTION**
       The computerized system according to an example embodiment of

4

the present invention determines the existence and magnitude

of a tooth-size discrepancy, the necessary anatomical

correction, the identity of the individual tooth or teeth

responsible for the tooth-size discrepancy and the recommended

5   arch wire size to effectuate treatment of the tooth-size

discrepancy. The computerized system includes a computer with

various input/output devices that include a computerized

caliper. The computer executes a program that performs an

analysis and outputs (1) the sums of the maxillary and

10   mandibular arches, (2) the necessary anatomical correction,

(3) the individual tooth or teeth responsible for the tooth-

size discrepancy and (4) the recommended arch wire size. The

computerized caliper is used to measure the mesiodistal width

of each tooth. The computerized caliper directly inputs each

15   tooth-size measurement into the computer.

Once the user has inputted the individual measurements for the

teeth involved in the analysis, the user may compare the

measurements with the average measurement for each tooth via a

20   monitor and/or a printer output.

Using the inputted information, the program determines the

magnitude of the tooth size discrepancy, the necessary

anatomical correction and the recommended arch wire size.

25   Once the tooth-size discrepancy is determined, the user may

utilize the necessary anatomical correction along with a

5

comparison of the measurements to the average sizes to

determine the proper diagnosis, i.e., how much correction to

make in the maxillary teeth, the mandibular teeth or a

combination of the two.

5

The method according to the example embodiment of the present

invention uses the selected arch wires during the entire

course of treatment. The arch wires are selected on the basis

of the tooth-size measurements of the patient.

10

In other embodiments, the constants used to calculate the

tooth-size discrepancy, anatomical correction necessary, and

the arch wire size are adjusted for the statistical

differences based on race.

15

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a computer system according to the

present invention.

20   Figure 2A illustrates a first screen display of a program

according to the present invention.

Figure 2B illustrates a second screen display of a pull down

menu from the screen display shown in Figure 2A.

25

Figure 2C illustrates a third screen display of a program

implementing the flow chart shown in Figure 3.

Figure 2D illustrates a fourth screen display of a program
implementing the flow chart shown in Figure 3.

5

Figure 3 illustrates a flowchart of a software program
according to the present invention for determining tooth-size
discrepancy, necessary anatomical correction, individual teeth
responsible for the tooth-size discrepancy and a recommended
10   arch wire size for the maxillary and mandibular arches.

Figure 4 illustrates a view of a set of small medium and large
arch wires according to the present invention.

15   **DETAILED DESCRIPTION**

An example embodiment of the present invention is explained in
further detail with reference to the drawings. Figure 1
illustrates a computer system according to the present
invention. The computer system includes a central processing
20   unit 101, a first storage device 102, a second storage device
103, a dynamic memory device 104, and input/output devices
105, 106, 107, 108 and 109. The central processing unit 101
is for executing computer programs, in particular a software
program determining tooth-size discrepancy, necessary
25   anatomical correction, the tooth or teeth responsible for the
tooth-size discrepancy, and arch wire size, and for managing

7

and controlling the operation of the computer system.

The first storage device 102, such as a floppy disk drive, is coupled to the central processing unit 101 for reading and writing data and computer programs to and from removable storage media, such as floppy disks. The second storage device 103 is also coupled to the central processing unit 102 and provides a means for storing computer programs and data. The second storage device 103, however, may be, for example, a hard disk drive having a high storage capacity.

The dynamic memory device 104, for example a RAM, is coupled to the central processing unit 101. The computer system includes typical input/output devices, such as, for example, a keyboard 105, a mouse 106, a printer 108, and a monitor 109. The computer also includes an input/output device for measuring the mesiodistal width of teeth, such as, for example a computerized caliper 107.

In the example embodiment the computerized caliper 107 may be a digital caliper such as, for example, the Fowler "Max-Cal: The Computerized Caliper," order no. 54-200-000 or 54-200-0008. This device may be modified in accordance with the example embodiment. For example, the measuring tines may be retooled so that they are sharply pointed and appropriate for highly accurate measurement of individual teeth. The actual

teeth or a plaster model of the teeth may be measured. It
should be noted that if the actual teeth are measured, then
the computerized caliper should be sterilized.

5   A driver is provided to read the input from the caliper 107.
This driver is capable of detecting each measurement taken by
the caliper 107 after an enter button of the caliper 107 has
been pressed. The driver, for example, determines which
communications port of the computer system shown in Figure 1
10   the caliper is connected. Further, the driver, for example,
establishes a communications link between the caliper 107 and
the computer system.

Figure 2A illustrates a screen display in which the user
15   enters patient information, for example, the patient's name,
age and gender and any missing or malformed teeth.

Figure 2B illustrates a pull-down menu 205 for selecting
whether the keyboard 105 or the caliper 107 will be used to
20   input the measurements. If the measurements will be entered
via the keyboard 105, the user should select none. If the
measurements will be entered via the caliper 107, the user
should select the communicatio port, i.e. COM1, COM2, etc., to
which the caliper 107 is connected. Once the user has
25   selected the input device and inputted the patient
information, the user must select the "NEXT" button to

implement the program shown in Figure 3.

Figures 2C and 2D are screen displays of a program implementing the flow chart shown in Figure 3. The program may be implemented using any conventional programming language, such as C++.

Figure 2C illustrates a screen display in which the user has inputted the individual tooth sizes necessary for a six-tooth analysis. As shown in Figure 2C, the user may select six-tooth analysis at radio button 201 or twelve-tooth analysis at radio button 202. The user may also select to input either the individual tooth sizes at radio button 203 or the sums of the maxillary and mandibular arches at radio button 204. In this case, the user has selected six-tooth analysis and to input the individual tooth sizes. These selections may be accomplished via the keyboard 105 or the mouse 107. If the user had selected to input the sums rather than the individual measurements, then the user inputs the sums at entry points 207 and 208 for six-tooth analysis and entry points 209 and 210 for twelve-teeth analysis.

At this stage, the user inputs the measurements via the keyboard 105 or the caliper 107. If the user has selected the keyboard 105 as the input device, the user enters the measurements in the order indicated using the keyboard 105 and

press the enter key of the keyboard 105. In the example

embodiment, the order for entering the measurements is

indicated by highlighting the measurement to be taken as shown

at entry point 206. Above entry point 26, the average size

5   for the upper right canine, 7.91 mm, is shown.

If the user has selected the caliper 107 as the input device,

the user uses the caliper 107 to measure the mesiodistal width

of each of the teeth and presses the enter button on the

caliper 107 after each measurement. After all the

10   measurements are entered the user should click on the "print"

button 211 and/or "calculate" button 212. The "print" button

211 prints out the screen display as shown in Figure 2C with

all of the inputted measurements. The "calculate" button 212

15   executes the determination of the arch size, tooth-size

discrepancy, necessary correction, and the arch wire size,

resulting in a screen display as shown, for example, in Figure

2D.

20   Figure 2D illustrates a screen display of an analysis summary

of an output of a program implementing the flow chart shown in

Figure 2. The screen display shows the maxillary arch sum

213, mandibular arch sum 214, any necessary anatomical

correction 215, 216, and the recommended arch wire size 217.

25   In this particular case, the sum of the maxillary arch is

44.28 mm and the sum of the mandibular arch is 36.19 mm. The

necessary anatomical correction is an increase in the maxillary arch by 2.6 mm or a reduction of the mandibular arch by 2.01 mm. This indicates that the mesiodistal width of the maxillary teeth should be increased by 2.6 mm, and the

5   mesiodistal width of the mandibular teeth should be decreased by 2.01 mm. The orthodontist, however, may also decide to implement a treatment that is a combination of the two calculations. The recommended arch wire size 217, in this case, is "small."

10   The teeth responsible for the tooth-size discrepancy may be determined by viewing the screen display shown in Figure 2C after inputting all of the individual teeth measurements. This particular screen display shows the average size for each

15   tooth either above or below the tooth's measurement. For the maxillary teeth, the average size is displayed above each measurement. The average size for the mandibular teeth is displayed below each measurement. The user may determine the teeth responsible for the tooth-size discrepancy by comparing

20   the measurement to the average size for each particular tooth.

Figure 3 illustrates a flowchart of a software program determining tooth-size discrepancy, the necessary tooth-size correction, the individual teeth responsible for the tooth-

25   size discrepancy, and arch wire size according to the present invention.

During execution of the program, a user selects either six or twelve via the keyboard 105 or the mouse 106 to indicate whether six-tooth analysis or twelve tooth analysis will be used (Block 301). Next, the program determines whether six-tooth or twelve tooth analysis was selected (Blocks 302 and 304). If the user indicated six-tooth analysis, the ideal mathematical ratio R is set to 0.772 (Block 303). If the user indicated twelve-tooth analysis, the ideal mathematical ratio is set to 0.913 (Block 305), otherwise the program returns to the beginning of the program (Block 301).

After the ideal mathematical ratio R is set, the program determines whether individual tooth sizes or the sums of the individual tooth sizes of each arch will be entered (Block 306). If the sums are to be entered, the user inputs the sum of the mesiodistal widths of the maxillary teeth U (Block 307). Likewise, the user inputs the sum of the mesiodistal widths of the mandibular teeth L (Block 308). If the mesiodistal widths for the individual teeth are to be inputted, the user is prompted to input the individual mesiodistal widths for the maxillary teeth and the sum of the mesiodistal widths of the maxillary teeth U is determined (Block 309). Likewise, the user is prompted to input the individual mesiodistal widths for the mandibular teeth and the sum of the mesiodistal widths of the mandibular teeth L is determined (Block 310).

Next, the necessary anatomical correction in the maxillary and

mandibular arches are determined. The magnitude of the

necessary anatomical correction in the maxillary arch, X, is

rounded to the nearest hundredth of millimeters(Block 311).

5

The necessary anatomical correction for the maxillary arch, X,

is determined according to the following equation:

$$X = L/R - U \tag{1}$$

The necessary anatomical correction for the mandibular arch,

Y, is determined according to the following equation:

$$Y = (U \times R) - L \tag{2}$$

Then, the necessary anatomical correction for the maxillary

arch, X, is compared to zero (Block 312). If the necessary

anatomical correction for the maxillary arch, X, is greater

than zero, then the program outputs that the mesiodistal width

20   of the teeth in the maxillary arch should be reduced by the

rounded X (Block 313). If the necessary anatomical correction

for the maxillary arch, X, is less than zero, then the program

outputs that the mesiodistal width of the teeth in the

maxillary arch should be increased by the rounded X (Block

25   314). If the necessary anatomical correction for the

maxillary arch equals zero, then there is no tooth-size

discrepancy and no anatomical correction is necessary.

Next, the magnitude of the necessary anatomical correction in
the mandibular arch, Y, is rounded to the nearest hundredth of
5   millimeters (Block 315).

The necessary anatomical correction in the mandibular arch, Y,
is then compared to zero (Block 316). If the necessary
anatomical correction, Y, is greater than zero, then the
10   program outputs that the mesiodistal width of the teeth in the
mandibular arch should be reduced by the rounded Y (Block
317). If the necessary anatomical correction, Y, is less than
zero (0), then the program outputs that the mesiodistal width
of the teeth in the mandibular arch should be increased by the
15   rounded Y for the mandibular arch (Block 318). If the
necessary anatomical correction, Y, for the mandibular arch
equals zero, then there is no tooth-size discrepancy and no
anatomical correction is necessary.

20   Finally, the recommended arch wire size is selected and
displayed to the user (Block 319). If the sum of the
maxillary teeth is less than 44.5 mm, then a set of small arch
wires is selected for the maxillary and mandibular arches. If
the sum of the maxillary teeth is greater than 44.5 mm but
25   less than 49.4 mm, then a set of medium arch wires is selected
for the maxillary and mandibular arches. If the sum of the

15

maxillary teeth is greater than 49.4 mm, then a set of large arch wires is selected for the maxillary and mandibular arches. These parameters were determined based on the standard deviation of the average sum of the maxillary anterior tooth sizes of the patients with an untreated ideal occlusion used in the Bolton scientific study.

Once the necessary anatomical correction in the maxillary and mandibular arches has been calculated according to the present invention, the orthodontist may select a conventional method of treatment. The orthodontist may correct the arch size discrepancy by one or a combination of the following methods:

1. Selective and measured reduction of the mesiodistal widths of selected teeth by interproximal stripping (reduction of the enamel surfaces by the necessary correction).

2. Extraction.

3. Prosthetic replacement of teeth or addition of teeth in accordance with the necessary correction.

4. Prosthetic treatment utilizing composite additions, veneers or jacket crowns altering the size of existing teeth.

The recommended arch wires should be used during the entire

course of treatment. In the example embodiment, the selected

arch wires are used through the entire course of treatment,

i.e., from beginning through the end. Use of an arch wire

5   according to the present invention, addresses three problems.

First, determination of the arch size by measurement of the

teeth assures, with few exceptions, that the treatment outcome

will provide facial and skeletal, functional and aesthetic

harmony with the patient's face and jaws. Second, the arch

10   wire selected by the present invention is adapted to the

individual patient's tooth-size preventing over-expansion or

constriction of the arch during the course of treatment.

Third, the arch wire according to the present invention may

prevent "round tripping" caused by moving teeth in wrong

15   directions and then correcting them again. Such movement may

create severe iatrogenic sequelae.

Figure 4 is an illustration of a set of small, medium and

large arch wires according to the present invention. Each

20   set contains an arch wire for the maxillary arch and the

mandibular arch. The large arch wire for the maxillary arch

has an approximate radius of curvature of 28.0875 mm. The

large arch wire for the mandibular arch has a radius of

curvature approximately equal to 25.4625 mm. The medium arch

25   wire for the maxillary arch has a radius of curvature of

approximately 26.75 mm. The medium arch wire for the

17

mandibular arch has a radius of curvature of approximately
24.25 mm. The small arch wire for the maxillary teeth has a
radius of curvature of approximately 25.4125 mm. The radius
of curvature is approximately 23.0375 mm for the small arch

5   wire for the mandibular arch. The radius of curvatures for
each of the arch wires is determined from historical patient
data, with the small and large arch wires being plus and minus
one standard deviation.

10   The arch wires are made of, for example, stainless steel
and/or nickel-titanium (NiTi) and may be, for example, either
round, rectangular or square. The size for round arch wires
made of NiTi are, for example, 0.014 inch, 0.016 inch, and
0.018 inch. The dimensions for rectangular NiTi arch wire
15   are, for example, 0.016 inch x 0.016 inch, 0.016 inch x 0.022
inch, 0.017 inch x 0.025 inch, 0.018 inch x 0.025 inch, 0.02
inch x 0.02 inch, and 0.021 inch x 0.028 inch. The dimensions
for Bioforce arch wires are, for example, 0.016 inch x 0.016
inch, 0.016 inch x 0.022 inch, 0.018 inch x 0.018 inch, 0.018
20   inch x 0.025 inch, 0.02 inch x 0.02 inch, 0.021 inch x 0.028
inch.

The tooth-size discrepancy, necessary correction, and arch
wire size are determined using, in part, the ideal
25   mathematical ratio from the Bolton Analysis. The original
Bolton Analysis as described in the paper entitled "Disharmony

18

in Tooth Size and Its Relation to the Analysis and Treatment

of Malocclusion" included only Caucasian patients. In another

embodiment, the present invention adjusts its calculations to

compensate for the modest but statistically significant

5   difference specific to other races. The method and process

remain the same, however, the ideal ratio and average sizes

for individual teeth would vary based on these statistical

differences.